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CIRCUITS FOR THE OPERATION OF THE PROJECT MUSIC STORAGE SYSTEM

[UNCLASSIFIED TITLE]

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ABSTRACT
(Confidential)

The radar equipment developed under Project Music is an electronic storage, crosscorrelation radar device used for determining the characteristics of phase-coherent signal enhancement in the presence of noise and backscatter. It is also used for long-range studies of the ionosphere and the character of large-area returns, or backscatter. Sweep circuitry was developed for use in the storage system to provide a sufficient number of isolated storage elements to define completely the phase and frequency information contained in the i-f signal to be stored. Means of monitoring sweep registry, storage phase, and frequency fidelity were developed and incorporated, and a means of controlling storage-tube discharge factor was designed to allow single-copy operation.

PROBLEM STATUS

This is an interim report on one phase of the problem; work is continuing on this and other phases.

AUTHORIZATION

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MIPR 30-635-8-160-6136

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CIRCUITS FOR THE OPERATION OF THE PROJECT MUSIC STORAGE SYSTEM
(Unclassified Title)

INTRODUCTION

The electronic storage, crosscorrelation radar equipment developed under the requirements of Project Music was designed to be used as a research instrument. To this end, the Music radar system was designed to be flexible in its operation. The storage system for Project Music, which includes the storage-unit, target-switching, and readout circuitry, has been previously described.* The present report will delve into appended units of the storage system, such as the sweep generators supplying the waveforms used to drive the Radechon storage-tube deflection plates, the Radechon and dual-monitor-scope unblanking and marker generator, a storage-tube discharge-factor control unit to permit single-copy operation, and a dual monitor incorporating a signal-monitor oscilloscope and a sweep-alignment-monitor oscilloscope.

The input signal to the storage unit, taken from the i-f of a transmitter-monitor receiver, provides the copy of the transmitted rf burst which is stored at the Radechon storage unit (this stored signal is read out at a later time to coincide with a received echo). Phase and frequency information must be faithfully reproduced; thus a high order of sweep stability and linearity and a high order of circuit stability in all other circuitry associated with the Radechon are required.

OPERATION OF THE STORAGE SYSTEM

In order to make adequate use of the storage system, a number of associated units were designed and developed. These units and their interrelationships may be seen in the block diagram shown in Fig. 1. Of primary importance was the choice of a sweep to be used at the storage tube. A sufficient number of isolated elements had to be provided to define fully the phase and frequency information contained in a 400-kc rf of 250-μsec duration. The Radechon storage tube available provided more than 100 isolated elements per sweep. Thus, a five-line sweep of 50 μsec per line provided sufficient storage elements for the retention of the phase and frequency information contained in the 250-μsec, 400-kc rf burst. The requirement of complete isolation between storage elements precluded the possibility of crosstalk between elements, which would have degraded the signal information.

The five-line sweep could have been generated in two possible ways. The first type of five-line raster considered utilized interline flyback, and the second type used line-end turnaround. It was essential to preserve readout-signal amplitude during the transition period between lines, and this was possible only when the beam-scanning velocity was kept nearly constant during the entire 250-μsec sweep, which included the interline transition period. The second type of five-line raster sweep fulfilled the requirements and was adopted.

*C. L. Uniacke and G. K. Jensen, "The Storage System for Project Music," NRL Report 5338 (Confidential Report, Unclassified Title), August 3, 1959.

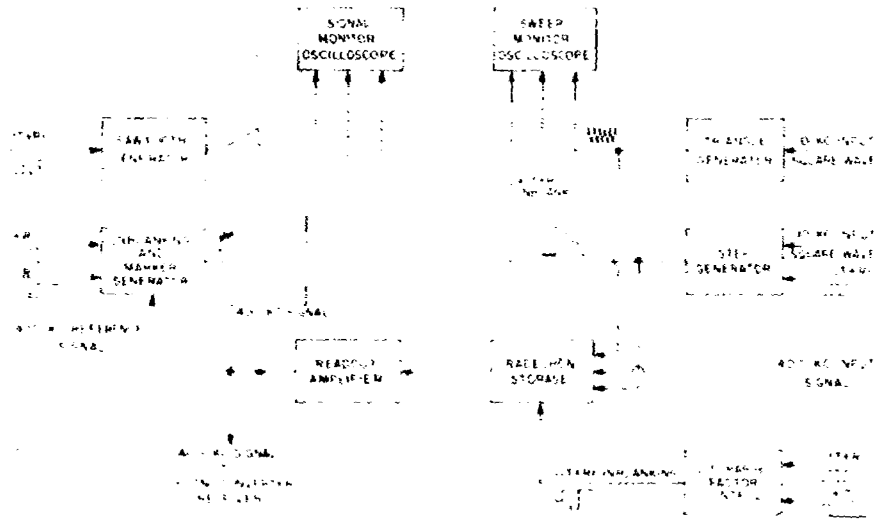

Fig. 1 - Block diagram of the Project Music storage system

Of paramount importance, then, in any consideration of the storage and readout of the signal is the full retention of phase and frequency information. Of necessity, it is equally important to generate a write sweep that is identical to the read sweep. Slight nonlinearities could be tolerated, but the sweeps, write and read, had to be perfect copies of each other, or undesired frequency and phase shift would be introduced. Sweep registration also had to be perfect in all respects for reading a true reproduction of what was written.

A sweep generator was developed which provided a step-sweep waveform for the vertical sweep with a high order of uniformity in the duration and amplitude of the steps and a high order of repeatability from sweep to sweep. A second sweep generator was developed which provided a triangular waveform of excellent linearity and reproducibility for the horizontal sweep. A combination of these sweep waveforms resulted in a five-line raster sweep meeting all the requirements.

A sweep-monitor oscilloscope, designed as half of a dual monitor, is used in the aligning of the write-read sweeps. The Radechon provides no visual means of determining the scan location on the target, so a sweep-position-monitor oscilloscope is a necessity. A necessity, also, is a signal-monitor oscilloscope; therefore, a sawtooth generator was needed to provide an extremely linear sawtooth waveform for the horizontal deflection system of this monitor. The 250-μsec, 400-kc rf signal burst from storage readout is used as the vertical deflection signal; the resulting presentation is used for determining the phase relationship and frequency of the transmitter exciter by comparison with a 400-kc reference frequency obtained from the radar system's master 100-kc crystal oscillator and applied as intensity modulation. Reference-frequency intensity markers are also used to verify the perfection with which phase and frequency information is retained at the output storage. In addition, the signal presentation is used to determine proper centering, amplitude, and focus of the signal on the Radechon target. The signal-monitor oscilloscope is gated on by an unblanking pulse applied to the crt cathode during the reading interval (400-kc intensity markers are also inserted for the phase and frequency measurements mentioned above). An unblanking and marker generator was designed to accomplish this purpose.

The Radechon is used as a single-copy device in the Music system, therefore nearly complete erasure occurs during the extraction of signal information or reading. It was necessary, then, to design a unit to allow flexible and independent control over the write and read conditions of beam current in order to permit writing at a relatively low beam current and reading at a somewhat higher beam current. This condition results in nearly complete erasure after a single read scan.

Triangle-Sweep Generator

Generation of a triangular-sweep waveform required the use of the 10-kc square-wave train from the Music system timer. This square wave is of approximately 30 volts peak-to-peak amplitude and, as shown in Fig. 2, is clamped and dc restored to swing between zero volt and approximately -10 volt bias. The waveform resulting from this processing is a square wave, improved in rise and fall time from the original input signal. Then the triode grid will swing from zero bias to a point approaching cutoff, with a resulting swing in plate current and the voltage at the plate. Charging condenser C1 has, during the negative portion of the input signal, charged to a value approaching the supply voltage. Upon reversal of the square-wave polarity, C1 discharges toward the lower value of plate voltage caused by conduction of the triode. Charge and discharge time constants of the generator, which are nearly equal, have been made many times greater than the time of one square-wave cycle, thus selecting a very short and consequently quite linear portion of the total charging curve represented by the component values. The triangular-sweep waveform thus generated drives a cathode follower and thence an output driving stage biased for linear operation. The output waveform is used as the horizontal sweep of the Radechon storage unit and the sweep-monitor oscilloscope. Input 10-kc square waves and the output triangular waves are illustrated in Fig. 3.

Step-Sweep Generator

The step-sweep generator, which generates the waveform used for vertical deflection at the Radechon storage tube and at the sweep-monitor oscilloscope, is shown schematically in Fig. 4. Input-pulse waveforms and the resulting step-waveform output are shown in Fig. 5. The rise and fall of the T and R pulses (transmit and receive) coincide with the rise and fall of the square waves and are maintained in perfect synchronization by the radar system timer.

A 10-kc square wave feeds a triode grid-crystal gate for improving the square-wave rise time and for limiting input amplitude variations. The phase-inverted output of this triode drives the first grid of a double-triode keyer as well as a second triode grid-crystal gate for rise-time improvement and amplitude limiting. The output of this triode drives the second grid of the double-triode keyer.

Both the single-inverted and double-inverted square-wave trains are sharply differentiated at the keyer grids. By using both inversions of the square waves, the succeeding one-shot multivibrator is keyed for each half cycle of the 10-kc square wave.

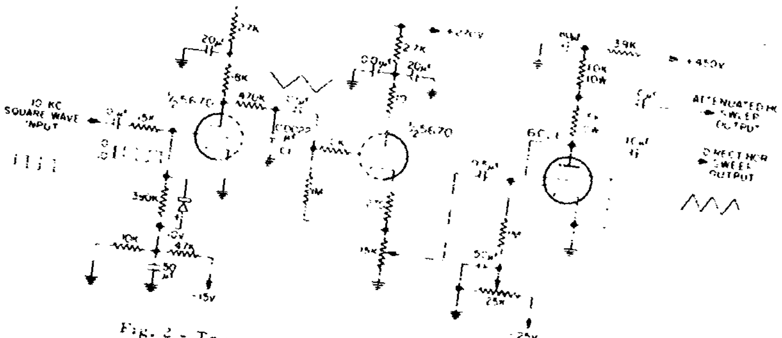

Fig. 2 - Triangle-sweep generator, schematic diagram

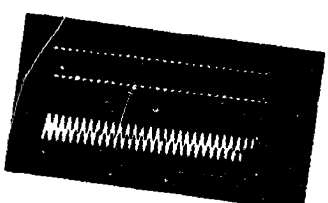

Fig. 3 - Triangle-sweep generator, waveform photograph

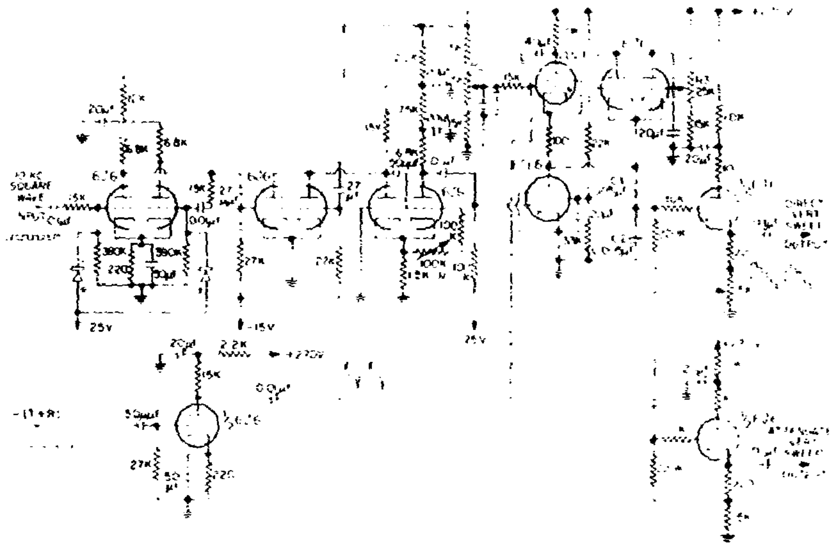

Fig. 4 - Step-sweep generator, schematic diagram

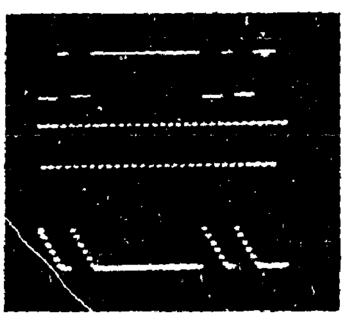

Fig. 5 - Step-sweep generator, waveform photograph

One-shot pulse width is set quite narrow to allow as little slope between steps as possible, in this case about 5 μsec. The pentode shown following the one-shot multivibrator operates at cutoff, except when keyed by a pulse, and capacitors C1 and C2 are discharged to a bias-line level set by R3 at the plate of the diode-connected double triode. The thyratron is adjusted by means of R2 to a grid-bias condition set just below cutoff. The -(T+R) pulses are amplified, and the output of the amplifier is differentiated. A positive pulse corresponding to the leading edges of the T and R pulses is then applied to the thyratron grid causing the thyratron to fire. Capacitors C1 and C2 are then charged through a 100-ohm resistor to approximately B+ level in a few microseconds. The next one-shot pulse causes C1 and C2 to discharge to the level of the next step, which is determined by the time duration of the one-shot pulse and the time constants of the discharging circuit. This step discharging process continues until the base line set by the diode clamp is reached. The total amplitude from first step to final step is determined by the range from about B+ to the diode-clamp level, and the number of steps within this range is determined by the one-shot pulse width. The steps are uniform, because the same incremental charge is removed from C1 and C2 at each step. A cathode follower is used to couple the step waveform from the voltage divider formed by C1 and C2 to the low-impedance output load.

Since the amplitude limits of the step waveform have been carefully controlled, each staircase waveform is identical to the previous one, regardless of the delay between the T and R pulses. As a consequence, no sweep-registry problems between write-in and readout sweeps exist at the Radechon storage tube.

If more information is to be stored, requiring more elements on the storage-tube target, the design of the step-sweep generator will allow a much larger number of lines to be used in the sweep pattern, assuming longer duration of the T and R pulses.

Sweep-Monitor Oscilloscope

The sweep-monitor oscilloscope (Fig. 6) is a complete unit by itself, but it is physically incorporated into a dual unit with the signal-monitor oscilloscope, which will be discussed subsequently. Push-pull deflection-plate drivers are in turn driven by the triangular-sweep waveform for the horizontal sweep and by the step sweep, as supplied to both the Radechon and the sweep-monitor oscilloscope, for vertical deflection. Pulses are formed in pairs, as previously discussed, one for the T portion of the T+R pulse group and one for the R portion. The R pulse is continuously variable in time in its relationship to the T pulse, and thus, to insure true scan retracing at the Radechon, the resulting two five-line scans shown on the oscilloscope, one for T and one for R, may be visually overlapped using the system-timer range-varying control. When visual overlap is attained, the quality of signal output from readout is an assurance that accurate scan retracing is taking place at the Radechon target. Input waveforms, synchronized in time, are shown in Fig. 7, an expanded view in Fig. 8, and the resulting presentation of the five-line sweep in sweep alignment with overlayed write and read sweeps in Fig. 9.

Sawtooth Generator

A sawtooth generator (Fig. 10) is used as the horizontal-sweep-waveform generator for the signal-monitor oscilloscope. It may be seen that the sawtooth wave is generated twice during the -(T+R) pulse interval, once for T and once for R. The length of the wave in both cases is 250 μsec. Photographs of the input and output waveforms are shown in Fig. 11.

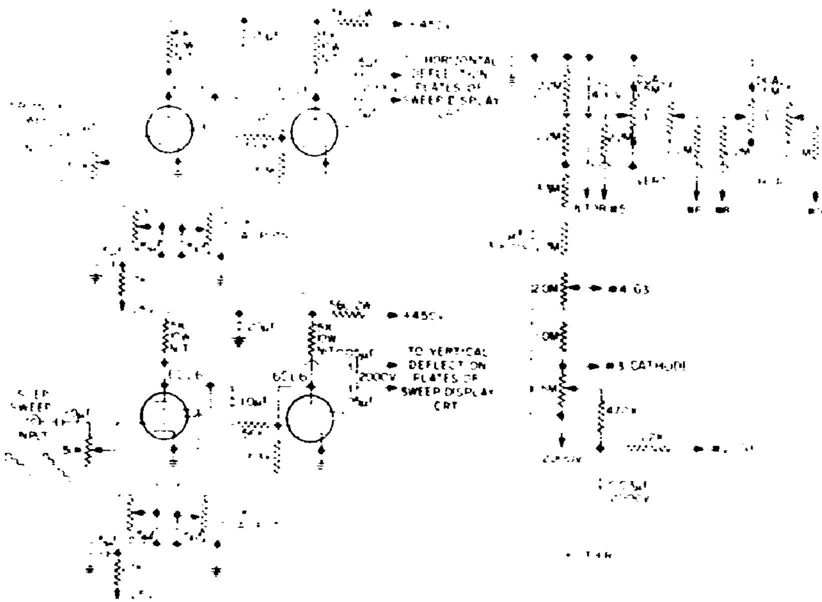

Fig. 6 - Sweep-monitor oscilloscope, schematic diagram

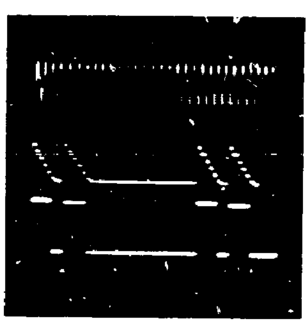

Fig. 7 - Sweep-monitor oscilloscope, waveform photograph

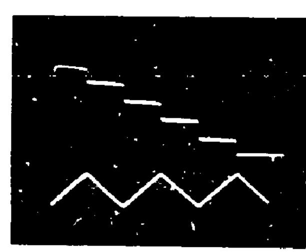

Fig. 8 - Vertical and horizontal waveform photograph, expanded view

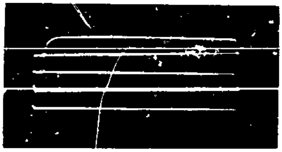

Fig. 9 - Five-line sweep

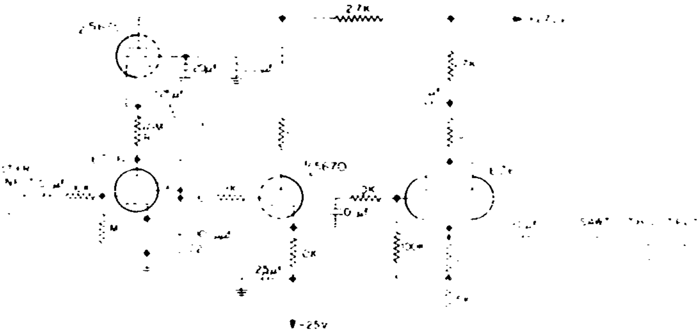

Fig. 10 - Sawtooth generator, schematic diagram

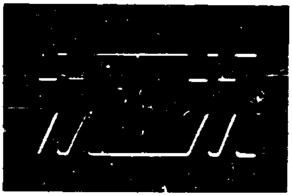

Fig. 11 - Sawtooth generator,
waveform photograph

The sawtooth generator consists of a switching pentode which draws its plate current through a diode, a triode cathode follower to supply feedback voltage, and an output cathode follower. The T pulse of the -(T+R) group cuts off the pentode switch, which also opens the diode charging path. Capacitor C1 (Fig. 10), having previously been fully charged, now loses charge through R1, thus charging C2 in turn. During the recovery period, or during the time following the return of the T pulse, the pentode conducts. The diode is also conducting, and one end of C1 is held at the supply level while C1 charges through the cathode resistor of the feedback cathode follower; the charging capacitor C2 discharges rapidly to the plate potential of the pentode. The resulting sawtooth wave is used as the input signal to the feedback cathode follower, whose output is fed to the diode end of resister R1. The voltage across R1 remains constant during the charging cycle; thus the sawtooth wave is extremely linear. This process is repeated for the R portion of the -(T+R) pulse group. The second cathode follower is provided to drive a low-impedance load.

Unblanking and Marker Generator

A schematic diagram of the unblanking and marker generator to be used with the signal-monitor oscilloscope is shown in Fig. 12. In this instance, a 400-kc reference signal is amplified in a tuned amplifier stage, which also effectively removes any extraneous modulation from the signal, and then is fed to the grid of an adder stage. A crystal clamp is employed here to prevent coupling-condenser back bias; a dual-diode clamp is applied to the signal at the coupling between stages. These clamping diodes are driven by the plus and minus R pulses and are biased in such a way that the clamp permits signal flow to the adder during the duration of the R pulse. The +R pulse is fed to the second adder grid, where it is crystal clamped and gated to improve its rise and fall time and to maintain constant amplitude. The 400-kc gated signal is added to the R pulse, amplified, and phase inverted in the output amplifier. The amplifier also serves as a low-impedance driver, the output of which is positive in polarity. This output serves as the combination marker and unblanking pulse for the signal-monitor oscilloscope. The pedestal gates on the beam, and the additional amplitude of the 400-kc sine-wave cycles furnish cycle-by-cycle intensity markers on the main 400-kc storage-readout signal displayed on the signal-monitor oscilloscope. Waveform photographs for this unit are shown in Figs. 13 and 14.

Stored-Signal-Monitor Oscilloscope

The stored-signal monitor is a complete unit, as is the sweep monitor, but it is incorporated in a dual unit with the sweep-monitor oscilloscope. Push-pull horizontal deflection-plate drivers are driven by the sawtooth waveform from the sawtooth generator. This sweep is 250 μsec long and of sufficient length to display the entire 400-kc signal as obtained from the storage readout. Push-pull vertical deflection-plate drivers are driven by the 400-kc signal from the storage-readout amplifier. Although both the T and R portions of the sawtooth horizontal sweep are fed to the push-pull drivers, the oscilloscope displays only the readout signal, since the scope is unblanked only during the R pulse interval. The +R unblanking pulse, as supplied from the unblanking and marker generator previously discussed, has the 400-kc reference sine-wave markers superimposed on it to intensify portions of the 400-kc readout signal. A complete schematic diagram of the stored-signal monitor is shown in Fig. 15, and the horizontal, unblanking, and vertical waveforms and the resulting presentation are shown in Figs. 16 and 17, respectively.

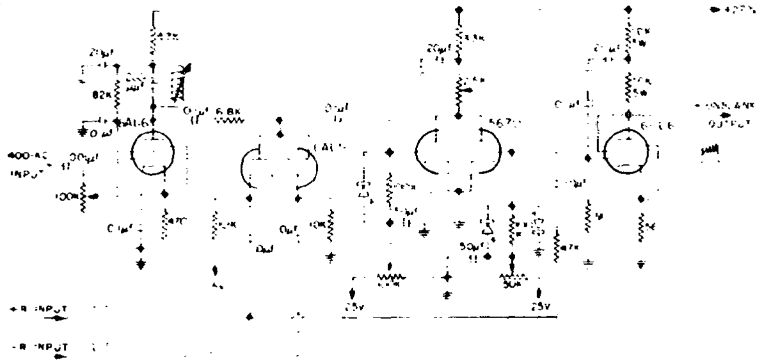

Fig. 12 - Unblanking and marker generator, schematic diagram

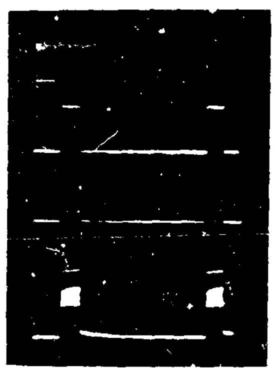

Fig. 13 - Unblanking and marker generator, waveform photograph

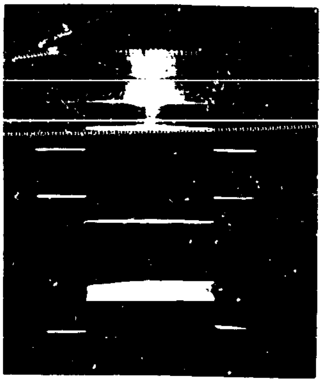

Fig. 14 - Unblanking and marker generator, waveform photograph, expanded view

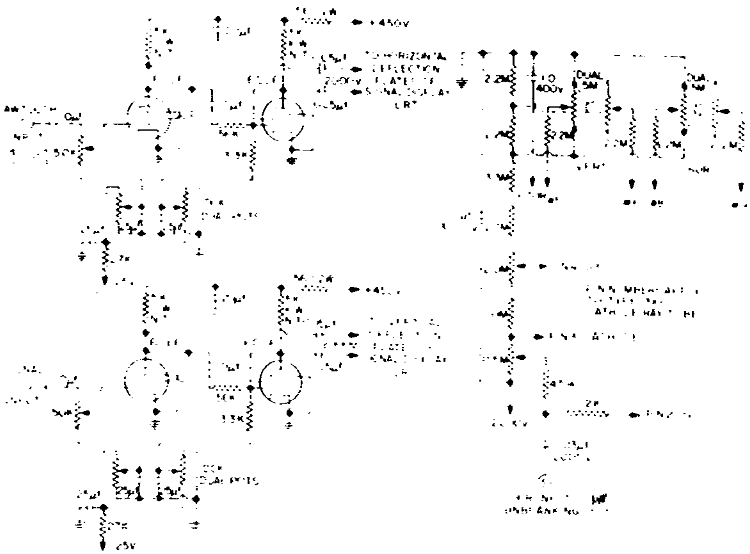

Fig. 15 - Signal-monitor oscilloscope, schematic diagram.

Discharge-Factor Control Unit

Radar operation of the Radechon storage tube required only a single copy of the stored information, with the consequent requirement of near-complete erasure during one reading sweep. It was evident that it would be desirable to read at high beam currents and to write at a somewhat lower level to make the single copy or the complete erasure practical. This made necessary the development of a variable-discharge-factor unit.

A schematic diagram for this unit may be found in Fig. 18. Here may be seen the use of the -(T+R) pulse group and its clamping by dual diodes. The pulse driver has in its grid circuit a crystal gate for +T pulse squaring and in its cathode circuit the control which adjusts the amount of T pulse clamping. This output driver is a phase-inverter low-impedance driver which furnishes the pulse train in both polarities. The term "±G(T+R)," G for gated, has been selected to differentiate this output from the ±(T+R) pulses available in the system. By varying the amplitude of the +T pulse at the clamping diode, the T portion of the ±G(T+R) pulse group is made variable in amplitude. This, then, is the control of writing level at the storage tube. Input pulses to the unit and final-output waveforms are shown in Fig. 19. It may also be noted that it is fully practical to substitute a +R pulse for the clamping pulse and thereby make variable the reading-beam current. This would allow multiple copies to be read from the storage surface.

It may be interesting to reiterate the pulse sequence as used at the storage unit,* now that a further insight has been established into the units generating some of the pulses used. Figure 20 shows an expanded view of the signals and pulses.

CONCLUDING REMARKS

The importance of sweep retraceability cannot be overemphasized. For proper operation of the storage system, the reading sweep had to retrace exactly the writing sweep; otherwise errors in phase and frequency of the readout would occur, as well as loss of amplitude. This required very close holding of linearity in the triangular sweep, from sweep to sweep, and good uniformity in the step length and spacing as well as very close holding of the position of the sweeps. The type of five-line sweep selected for use in the storage system was chosen to provide additional storage elements along the dropdown between steps. This type sweep has provided excellent results in supplying a clean phase-shift-free signal after storage. The presentation of this sweep on its monitor oscilloscope has proved valuable for sweep alignment between write and read and for detecting occasional malfunctions in the units.

Output from the storage system is also monitored on an oscilloscope. To make full use of this unit, a linear sawtooth waveform for the horizontal sweep was required. Linearity requirements here were also moderately stringent in order not to distort the readout-signal display. The oscilloscope was to be used in checking storage-tube overload, focus, sweep positioning on the target, setting of the discharge factor, and for measurement of the phase shift across the rf burst and the transmitter frequency by intensity-marker comparison.

The intensity-marker comparison was made between a standard 400-kc reference signal from the system master crystal and the 400-kc signal from the transmitter-monitor receiver. Intensity markers were designed into a common unit with an unblanking pulse

*Ibid.

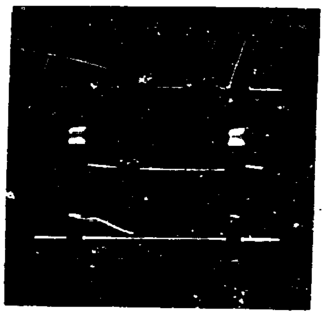

Fig. [illegible] – Signals [illegible] photograph

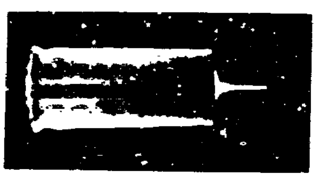

Fig. 17 – [illegible] photograph

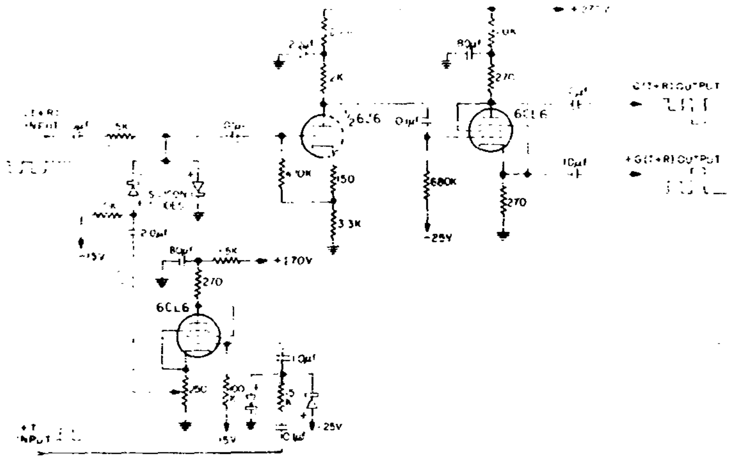

Fig. 18 - Discharge-factor control unit, schematic diagram

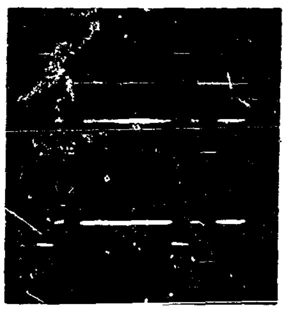

Fig. 19 - Discharge-factor control unit, waveform photograph

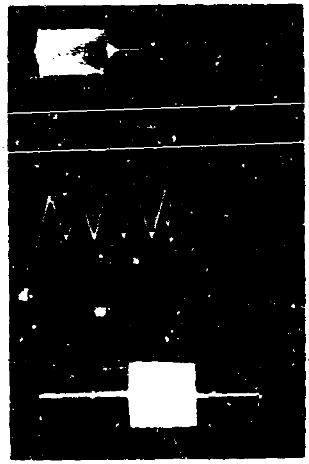

Fig. 20 - Radechon input and output waveform photographs

generator to be used to unblank the signal-monitor oscilloscope during the reading interval. This unit has proved very successful and useful in evaluating and using the Masic system.

The discharge-factor control unit also has been a valuable adjunct to the storage part of Project Masic. It was designed to be sufficiently flexible to allow variable writing-beam intensities with fixed reading-beam intensity as well as the possible use of the reverse of the above conditions. Single-copy erasure of the Radechon target was thus accomplished, but with the additional flexibility of multicopy readout for other potential uses.

ACKNOWLEDGMENT

The authors wish to acknowledge the help of Mr. James H. Veeder, without whose excellent work and sense of urgency at the early stages of design, development, and construction of the Masic radar the project would have been greatly delayed.

* * *

UNITED STATES GOVERNMENT
memorandum

5300-31

DATE: 29 June 1998

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SUBJECT: REQUEST TO DECLASSIFY NRL REPORTS

TO: Code 1221.1 (C. Rogers)

1. It is requested that the NRL Reports listed below be declassified. The information contained in these reports has become public knowledge in the many years since first classified.

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